Robotics in Gender Affirming Surgery: Current Applications and Future Directions

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Abstract

Genital surgery for the treatment of gender dysphoria has undergone significant evolution since its inception in the first half of the 20th century. Robotic approaches to the pelvis allow for improved visualization and reduced abdominal wall morbidity, making the robotic surgical system a very useful tool in the gender affirming genital surgeon's armamentarium. In penile inversion vaginoplasty, robotically harvested peritoneal flaps can be used to augment the vaginal canal, thereby leading to improved vaginal depth, as well as improve operative efficiency by facilitating a two-surgeon approach. In transgender men, the robotic approach to vaginectomy assists with visualization to confirm complete obliteration of the vaginal canal. Robotic surgery will play a central role in the continued evolution of the field of gender affirming surgery.

Keywords
- gender affirming surgery
- robotic surgery
- transgender
- bottom surgery
- vaginoplasty
- penile inversion vaginoplasty
- peritoneal flap vaginoplasty
- Davydov flap
- single port robot
- da Vinci SP
- vaginectomy

Genital surgery for the treatment of gender dysphoria has undergone significant evolution since its inception in the first half of the 20th century.[1] Some of the earliest techniques for gender affirming vaginoplasty involved placing skin grafts taken from the amputated penis over a mold to line the vaginal cavity.[2] In the 1950s, surgeons began lining the neovaginal canal with anteriorly based penile skin flaps, a technique that has come to be known as the penile inversion vaginoplasty.[3] Continued technical advancements have focused on refining the penile inversion vaginoplasty with the goal of creating an aesthetically pleasing vulva, a vaginal canal of sufficient depth and width to allow for penetrative intercourse, a sensate clitoris that is capable of sexual arousal and climax, urinary continence with a downward-pointing urinary stream, and minimal secondary donor site morbidity. The majority of penile inversion vaginoplasty techniques that involve a single surgeon using an open transperineal approach have several limitations including reduced visibility during the deep pelvic dissection and, in cases of penoscrotal hypoplasia, limited natal genital tissue for both vulvar reconstruction and vaginal canal lining. The application of robotic techniques in pelvic surgery allows improved visualization, less blood loss, and in gender affirming vaginoplasty the ability to augment the vaginal canal with peritoneal flaps. Since the senior authors' initial description of the robot-assisted peritoneal flap vaginoplasty,[4] indications for use of the robotic surgical system in gender affirming genital surgery have expanded to include revision vaginoplasty as well as primary and secondary vaginectomy.[5–8] In this article, the authors describe their experience and review their

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outcomes data applying robotic techniques to a range of gender affirming genital surgeries.

Single Port versus Multi Port Robotic Systems

Initial descriptions of robotically assisted gender affirming surgery used the da Vinci Xi robot system (Intuitive Surgical Inc., Sunnyvale, CA) for the dissection of the vaginal canal in vaginoplasty.[4] The Xi system has four robotic arms, which are used to access the peritoneal cavity through four to five separate ports based on positioning and instrument needs. More recently, the da Vinci Single-Port (SP) system (Intuitive Surgical Inc.), in which a single port allows control of three multijointed surgical instruments as well as an articulating endoscope, has been used. In this system, typically two access ports are required, one for the robotic trocar and one for a laparoscopic assistant port (►**Fig. 1**).

The SP system provides several benefits when compared to the Xi system.[9] The SP approach requires fewer access incisions, which decreases the abdominal scar burden. In addition, in the SP system the single arm can be brought in laterally and overhang directly over the abdomen, whereas in the Xi system the four robotic arms typically overhang the perineum and can obstruct the perineal surgeon (►**Fig. 2**). The SP configuration therefore better facilitates a two-team approach with the robotic and perineal surgeons working simultaneously. The design of the SP system, with all instruments emanating from a single port, also facilitates access to the deeper portions of the vaginal canal dissection, in which the working space is narrower. In the Xi system, the multiple robotic arms can clash with the lateral sidewalls of the narrow working space at the deepest part of the peritoneal flap harvest and during intracorporeal suturing.[10] When directly comparing peritoneal flap vaginoplasty approaches, the SP robot system has been shown to significantly reduce total operative time with no change in complication rates relative to the Xi system.[9]

Penile Inversion Vaginoplasty

Among gender affirming surgeries, the use of the robotic surgical system has been most extensively applied to gender affirming vaginal reconstruction.[4,9,11–15] Non-robot-assisted penile inversion vaginoplasty techniques involve dissecting a neovaginal canal between the prostate and the rectum from an external perineal incision and lining that canal with a combination of penile skin flaps, scrotal or abdominal skin grafts, and/or acellular dermal matrix.[16] This technique presents several challenges, including (1) limited visibility of the deepest part of the canal dissection and (2) limited genital tissue for canal lining in cases of penoscrotal hypoplasia. Robot-assisted peritoneal flap penile inversion vaginoplasty, first described by the senior authors in 2019, seeks to address these challenges by facilitating improved visualization during canal dissection and simultaneously harvesting peritoneal flaps for additional canal lining.[4] This technique has been described in detail[4,13] and is summarized below.

Surgical Technique

The patient is placed in dorsal lithotomy with arms tucked and approximately 30 degrees of Trendelenburg. A Foley catheter is placed. The adductor longus tendons are marked bilaterally and a 2 cm × 1 cm posteriorly based rhomboid flap is marked in the perineum anterior to the anus. The area for scrotal skin graft harvest is marked as an ellipse over the central, rugated scrotum extending from the rhomboid flap to the base of the scrotum. A line is marked 2 cm proximal to the corona and extended circumferentially around the penile shaft.

The scrotal skin is harvested as a full-thickness graft superficial to the dartos fascia and thinned on a back table. Orchiectomy is performed if the patient has not had their testicles previously removed. The spermatic cord is ligated proximally to the inguinal ring to facilitate complete retraction of the stump into the inguinal canal. The penile skin is

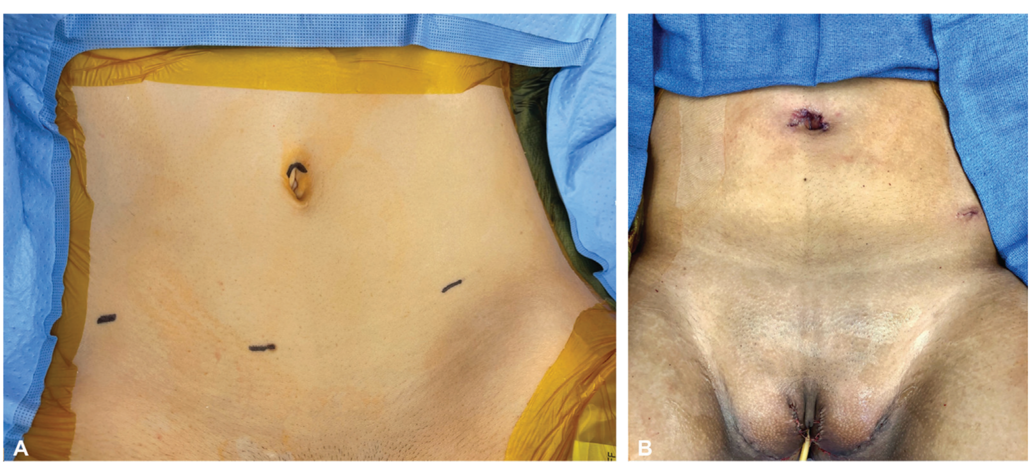

Fig. 1 Common port site incision designs for (**A**) the da Vinci Xi robot versus (**B**) the SP robot.

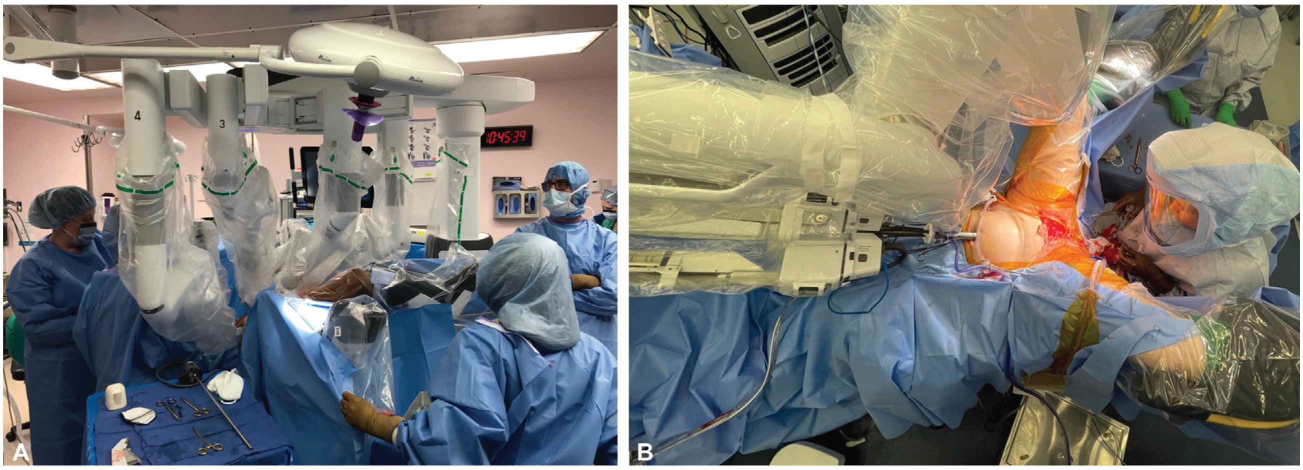

Fig. 2 Common arrangement of robot arms for (**A**) the da Vinci Xi robot versus (**B**) the SP robot.

incised and the penile shaft is degloved within the loose areolar plane between the dartos and Buck's fasciae. The shaft is delivered through the penile skin tube. The prepuce and glans are divided at the ventral midline and the urethra is dissected free from the remaining shaft structures to the level of the adductor longus, at which point the freed urethra is amputated and discarded. The bilateral corpora cavernosa are incised exposing the erectile tissue, which is bluntly dissected off the tunica albuginea and discarded. The intercorporeal septum is removed and the proximal corpora cavernosa are closed. The central penile glans is excised and the lateral wings de-epithelialized to create a 2×1 cm central glans flap bordered by preputial skin. The lateral wings are sutured together to create the clitoris. The tunica is folded on itself and fixed to the suprapubic soft tissue to set the location of the clitoris.

External vaginal canal dissection begins with incising Colles' fascia at the midline exposing the bulbospongiosus muscle, which is separated from the corpus spongiosum. The remaining proximal urethra is split ventrally at the level of the corpus cavernosum decussation and the lateral borders of the split urethra are inset to the preputial skin remaining on the clitoris. The plane between the bulbospongiosus and corpus spongiosum is developed to the apex of the prostate, at which point dissection meets with the robotic surgeon. The vaginal canal is widened by dividing the levator ani and the pelvic sidewall musculature until a 38-mm Soul Source dilator (North Hollywood, CA) is able to be passed easily.

Simultaneously with penile disassembly, intraperitoneal access is obtained via a supraumbilical incision and 2.7-cm vertical fasciotomy and the robotic platform is docked. Our preferred robotic system is the da Vinci SP, with the following instruments: bipolar Maryland forceps, monopolar scissors, and a needle driver. A combination of Trendelenburg and retraction via a laparoscopic assistant port facilitates exposure of the rectovesical space. The peritoneum is incised transversely at the level of the vas deferens and a plane is developed within Denonvilliers' fascia between the prostrate and the rectum. Dissection proceeds posterior to the seminal vesicles toward the rectum until the robotic and perineal dissections meet. Adequate vaginal canal width is confirmed by passing a 38-mm dilator.

Approximately 12×12 cm anterior and posterior peritoneal flaps are then raised from the posterior aspect of the bladder and anterior border of the rectum, respectively. The ureters mark the lateral borders of the flaps. Externally, the scrotal skin graft is tubularized around a 38-mm dilator and inset to the inverted penile skin tube. This penoscrotal skin is passed through the vaginal canal to the robotic surgeon, who insets the penoscrotal skin tube to the peritoneal flaps using a barbed 3–0 absorbable suture. The anterior and posterior peritoneal flaps are sewn together at the apex of the neovagina and the flap donor sites are closed. The vaginal canal is packed with antibiotic-soaked gauze. The robot is undocked and the abdomen closed in the standard fashion.

Labiaplasty is completed by insetting the inverted penile skin to the perineal rhomboid flap, which becomes the floor of the vaginal canal. The penile skin is incised over the clitoris and urethra and the Foley catheter delivered. The medial edge of the penile skin is inset to the lateral edge of the preputial skin and horizontal mattress sutures are used to define the labia minora and clitoral hood. The medial edge of the remaining scrotal skin is inset to the lateral edge of the inverted penile skin to create the labia majora. A negative pressure dressing is placed on the vulva and secured with an external compression dressing.

Surgical Outcomes

Proposed benefits of the robotically assisted peritoneal flap vaginoplasty over the traditional penile inversion vaginoplasty include improved visualization during vaginal canal dissection and greater potential vaginal depth, particularly in patients with limited natal genital soft tissue.[4,9,11,13] At our center, the average vaginal canal depth is 14.5 cm in patients with a median follow-up of 1 year.[17] These data compare favorably to a recent meta-analysis of 39 studies encompassing more than 3,900 patients undergoing traditional penile inversion vaginoplasty, which reported an average vaginal depth of 9.4 cm.[18] In addition, we have found that using the robotic peritoneal flap approach, our vaginal depth outcomes are equivalent between patients with penoscrotal hypoplasia and those with greater genital tissue surface area.[17] Historically, patients with marked penoscrotal hypoplasia have been encouraged to pursue intestinal vaginoplasty.[19,20] The robotically assisted peritoneal flap vaginoplasty offers an alternative to colon vaginoplasty for these patients.

In addition to improved vaginal depth, the use of the robotic surgical system to raise vascularized peritoneal flaps for additional vaginal canal lining is hypothesized to lead to lower rates of vaginal stenosis. Meta-analysis of traditional penile inversion techniques report an average vaginal stenosis and/or stricture rate of 10%.[18] In our experience with the da Vinci SP robot, at an average follow-up of 1 year, 2% of patients experienced vaginal stenosis as defined by being unable to dilate greater than 10.9 cm.[9] Additional multicenter research is needed to examine whether there is a reproducible benefit in vaginal canal dimensions and complication rates between traditional and robot-assisted penile inversion vaginoplasty techniques.

Patients seeking revision vaginoplasty may benefit from robotically assisted surgery.[21] The most common indication for canal revision is vaginal stenosis. Rarer indications for canal revision include vaginal prolapse and canal malposition. Traditional perineal approaches in revision vaginoplasty can be technically difficult due to limited visibility with extensive scar tissue and the proximity of the stenosed vagina to the bladder and rectum. Additionally, the robotic approach offers a concealed donor site, the peritoneum, for lining the revised vaginal canal.[22] In our experience, vaginal canal revisions can be successfully performed using peritoneal flaps that are harvested in a similar fashion to the primary vaginoplasty technique described earlier and sutured to the remnant existing canal once the stenosis has been incised and released.[22] In approximately 10% of cases, the peritoneal flaps could not reach the vaginal canal remnant for primary inset. In these cases, full-thickness skin graft or acellular dermal matrix, which obviates the need for a secondary donor site, can be used to line the interval between the peritoneal flaps and the remnant canal.[23]

Vaginectomy and Urethral Lengthening

Robotic techniques have also been applied to masculinizing genital surgery, specifically vaginectomy in the setting of metoidioplasty or phalloplasty.[5] Vaginectomy seeks to completely excise all vaginal epithelium while avoiding injury to the nearby bowel, bladder, urethra, and ureters. Remnant vaginal mucosa has been associated with increased urethral complication including urethrovaginal fistula, post-void dribbling due to retained urine within the remnant vaginal canal, perineal pain, and recurrent urinary tract infections.[5,24,25] The perineal approach is the most common technique used for vaginectomy and can be associated with difficult operative visualization. A recent study of perineal vaginectomy reported a 10% major complication rate including injury to the bowel, bladder, ureter, and/or urethra.[26–28] Robotic transabdominal approaches to vaginectomy allow better visualization of the deep pelvis and facilitate more complete excision of the vaginal epithelium with less risk of injury to nearby structures.

Surgical Technique

A two-team approach is utilized for the vaginectomy and urethral lengthening, with both a perineal and a robotic surgeon working simultaneously. The vaginal epithelium is stained with methylene blue, and the plane between the epithelium and muscle is infiltrated with lidocaine and epinephrine. The perineal surgeon incises the posterior and lateral vaginal walls at the level of the introitus. A 2×1 cm flap of anterior vaginal epithelium immediately below the urethral meatus is preserved for later incorporation into the urethroplasty. Dissection proceeds proximally as the vaginal epithelium is sharply dissected free from the underlying pelvic musculature. Concurrently pneumoperitoneum is established and the robotic access to the pelvis is achieved. A vaginal dilator is placed to identify the apex of the vaginal canal. The robotic surgeon incises the vaginal apex and dissects the posterior vaginal epithelium off of the rectum. Dissection continues circumferentially around the vaginal canal until the entire vaginal epithelium—with the exception of the anterior vaginal mucosa flap—is freed and can be removed and discarded. A pedicled gracilis muscle can be used to obliterate the vaginal cavity. The gracilis is split longitudinally using electrocautery to create two vascularized muscle strips. The inferior muscle hemiflap is passed to the robotic surgeon and inset to the de-epithelialized vaginal wall using a running 3–0 barbed absorbable suture, ensuring complete eradication of dead space following vaginectomy.

Surgical Outcomes

Robotic-assisted vaginectomy offers improved visualization and the ability to fixate well-vascularized muscle into the vaginal canal and reinforce proximal urethral reconstruction. In our experience, this robotically assisted vaginectomy and urethroplasty with split gracilis reinforcement technique is associated with an 8% rate of pars fixa stricture and 8% rate of pars fixa fistula.[8] This is a marked reduction in urethral complication rates, which historically have been cited to be as high as 50 to 80%.[7,29,30] In addition, we have not observed any patients with persistent vaginal remnants.[5,8] Other studies have reported high rates of persistent vaginal remnant, up to 50%.[24,30]

In addition to primary vaginectomy and urethral lengthening, we have observed the benefit of the robotic approach in revision vaginectomy for vaginal remnant and/or urethral diverticulum.[6] In the case of incomplete vaginectomy, fistulae may form between the urethra and the remnant vaginal mucosa, creating a urethral diverticulum in turn causing postvoid dribbling, perineal pain, and recurrent urinary tract infections. Perineal approaches to excision of remnant vaginal tissue have limited visualization and require reopening the previous perineorrhaphy, risking injury to the reconstructed urethra. The robotic transabdominal approach offers more direct visualization and allows for completion vaginectomy without recreating the perineal incision. A cystoscope is inserted into the urethral diverticulum and guides the robotic dissection of the remnant vagina. Once the entire remnant vagina has been resected, the mucosal defect is closed with a running 3–0 V-Loc suture. Saline is instilled through the cystoscope to ensure watertight closure. We previously published on four patients who underwent robotic-assisted excision of the vaginal remnant, and at 13 months of follow-up no patients were found to have a recurrent diverticulum on cystoscopy.[6]

Conclusions and Future Directions

The robotic-assisted surgery represents a powerful and evolving tool in the gender affirming genital surgeon's armamentarium. In our experience, the robotic approach facilitates improved visualization, greater operative efficiency, and improved surgical outcomes in a range of primary and revision genital surgeries including vaginoplasty and vaginectomy. As additional centers adopt the robotic approach, multicenter prospective data are expected to clarify the benefits and limitations of robotic approaches to gender affirming surgery. We believe it is important to incorporate robotic techniques into the surgical education of trainees interested in gender affirming genital surgery. A continued emphasis on multidisciplinary care and close cooperation between plastic surgeons and reconstructive urologists is critical for further evolving the field of gender affirming surgery.

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Conflict of Interest
None declared.

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